



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<b>(21) International Application Number:</b> PCT/US99/03700 <b>(22) International Filing Date:</b> 19 February 1999 (19.02.99)  <b>(30) Priority Data:</b> 60/075,613      20 February 1998 (20.02.98)      US 60/110,150      25 November 1998 (25.11.98)      US  <b>(71) Applicant (for all designated States except US):</b> CITY OF HOPE [US/US]; 1500 East Duarte Road, Duarte, CA 91010-3000 (US).  <b>(72) Inventors; and</b> <b>(75) Inventors/Applicants (for US only):</b> COMINGS, David, E. [US/US]; 59 Crestview Court, Duarte, CA 91010 (US). MACMURRAY, James, P. [US/US]; 1115 N. Yale, Claremont, CA 91711 (US).  <b>(74) Agents:</b> KARTA, Glenn, E. et al.; Rothwell, Figg, Ernst & Kurz, Suite 701 East, 555 13th Street N.W., Columbia Square, Washington, DC 20004 (US).		<b>(81) Designated States:</b> AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>Without international search report and to be republished upon receipt of that report.</i>
<b>(54) Title:</b> ASSOCIATION OF THE SEROTONIN TRANSPORT (HTT) GENE WITH CARDIOVASCULAR DISEASE AND LONGEVITY		
<b>(57) Abstract</b>  Disclosed are methods for screening subjects to determine their risk for developing cardiovascular disease, screening methods to determine potential longevity, therapeutic methods and compositions for treating patients at risk for developing cardiovascular disease, and screening methods for identifying materials useful in the therapeutic methods.		

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## TITLE OF THE INVENTION

ASSOCIATION OF THE SEROTONIN TRANSPORT (HTT) GENE WITH  
CARDIOVASCULAR DISEASE AND LONGEVITY

5

## CROSS-REFERENCES TO RELATED APPLICATIONS

This application claims the benefit of U.S.  
Provisional Application No. 60/110,150 filed November 25,  
1998, and U.S. Provisional Application No. 60/075,613  
10 filed February 20, 1998.

STATEMENT REGARDING FEDERALLY SPONSORED  
RESEARCH OR DEVELOPMENT

Not applicable.

15

## BACKGROUND OF THE INVENTION

## 1. Field of the Invention

The present invention relates to the association  
between the serotonin transporter (HTT) gene and serum  
20 cholesterol levels, heart disease and longevity.

## 2. Description of the Related Art

The full citations of the publications referred to  
herein are found at the end of the specification. The  
25 contents of the references are incorporated herein by  
reference.

Low cholesterol levels have been reported to be  
associated with the development of depression and violent  
death by suicide, especially in the elderly (1-5). This  
30 occurs both in subjects in the general population and  
subjects whose cholesterol levels have been lowered by  
medication. Several possible mechanisms for these  
phenomena have been suggested including a decrease in  
serotonin levels (3, 6) or a decrease in the number of

membrane serotonin receptors or transporters due to the effect of low cholesterol on membrane fluidity (6). A link between serotonin levels and cholesterol was supported by studies in monkeys showing that those with  
5 cholesterol levels altered by diet showed a positive correlation between plasma cholesterol level and central serotonergic activity (7, 8). By contrast, a study by Fernstron, et al. (9) found no significant differences in tryptophan, serotonin or 5-HIAA concentrations in several  
10 brain regions in gerbils with a wide range of diet induced variations in cholesterol level.

Steegmans, et al. (10) reported a significant decrease in plasma serotonin, but not platelet serotonin, in 100 men in the general population with a demonstrated  
15 long term (3 years) cholesterol level below the fifth percentile compared to 100 control men with cholesterol levels in the 35th to 75th percentile. Smith and Betteridge (11) observed a significant negative correlation between platelet serotonin and cholesterol  
20 levels in subjects with hypercholesterolemia and controls ( $r$  for both combined =  $-.48$ ,  $p \leq 0.005$ ). In the hypercholesterolemic subjects there was a significant positive correlation with high-density lipoprotein (HDL) ( $r = .79$ ,  $p = .001$ ). They concluded there was a  
25 significant relationship between circulating cholesterol and platelet serotonin and that a serotonin uptake (transporter) mechanism was involved. Others have suggested the apparent association between low cholesterol and depression could be due to the fact that  
30 both were related to a third confounding factor, such as general poor health (12).

The observations that low cholesterol levels induced by medication or diet can be associated with depression suggest that environmental factors are involved and that

the low cholesterol was the primary event while the altered serotonin levels were secondary. However, the observation that low cholesterol levels in individuals in the general population can be associated with low  
5 serotonin levels and depression is compatible with the possibility that in some cases genetic factors could be responsible for either the low cholesterol, the depression, or both. The fact that elderly subjects are often involved suggests that some variables may be  
10 related to age. There is also a well documented association between depression and cardiovascular disease in general (13).

#### BRIEF SUMMARY OF THE INVENTION

15 In one aspect, the present invention relates to a method for screening a subject to determine whether such subject is at increased risk for developing cardiovascular disease, said method comprising determining the subject's genotype with respect to the  
20 serotonin transport (HTT) gene, wherein an LS heterozygote for the HTTLPR insertion/deletion polymorphism at the promoter region of the HTT gene has an increased risk for developing said disease.

In another aspect, the present invention relates to  
25 a method for screening a subject to determine whether such subject is a candidate for a therapy using a drug which prevents or treats a cardiovascular disease associated with excessive production of the serotonin transport protein, said method comprising determining the  
30 subject's genotype with respect to the serotonin transport (HTT) gene, wherein an LS heterozygote for the HTTLPR insertion/deletion polymorphism at the promoter region of the HTT gene is a candidate for such therapy.

In another aspect, the present invention provides a method for screening a subject to determine the potential longevity of such subject, said method comprising determining the subject's genotype with respect to the serotonin transport (HTT) gene, wherein an SS homozygote  
5 for the HTTLPR insertion/deletion polymorphism at the promoter region of the HTT gene has a greater probability of survival past eighty years of age.

In another aspect, the present invention relates to  
10 a method for treating a patient at increased risk for developing cardiovascular disease due to the patient being LS heterozygous for the HTTLPR insertion/deletion polymorphism at the promoter region of the serotonin transport (HTT) gene, said method comprising  
15 administering to said patient an effective amount of a material which diminishes the effect of the serotonin transporter protein.

In another aspect, the present invention relates to a method for identifying materials that can be used in  
20 the treatment of a patient at increased risk for developing cardiovascular disease due to the patient being LS heterozygous for the HTTLPR insertion/deletion polymorphism at the promoter region of the serotonin transport (HTT) gene, said method comprising determining  
25 whether the material is capable of diminishing the effect of the serotonin transporter protein.

In another aspect, the present invention relates to a pharmaceutical composition which comprises

a) an effective amount of a material which is  
30 capable of diminishing the effect of the serotonin transporter protein in a patient being LS heterozygous for the HTTLPR insertion/deletion polymorphism at the promoter region of the serotonin transport (HTT) gene; and

b) a pharmaceutically acceptable carrier.

In another aspect, the present invention relates to a kit suitable for screening a subject to determine whether such subject is at increased risk for developing cardiovascular disease, said kit comprising

a) means for determining the subject's genotype with respect to the insertion/deletion polymorphism at the promoter region of the serotonin transport gene;

b) suitable packaging material; and optionally

c) instructional material for use of said kit.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows the postulated relationships between the HTT genotypes, cholesterol, depression, and cardiovascular disease.

Figure 2 shows a partial sequence of the regulatory region of the serotonin transporter gene. [SEQ.ID.NO:1]

#### DETAILED DESCRIPTION OF THE INVENTION

The present invention is based on the observation that subjects having the LS heterozygote for the insertion/deletion polymorphism in the promoter region of the serotonin transporter (HTT) gene have an increased risk of developing cardiovascular disease, such as elevated cholesterol, angina and heart attacks. Additionally, subjects having the SS homozygote have a greater probability of survival past eighty years of age.

The present invention entails the determination of the subject's genotype with respect to the insertion/deletion polymorphism of the HTT gene described above. Such can be determined, for example, by analysis of the subject's DNA, RNA, or protein, with DNA analysis being particularly preferred. Suitable analysis

techniques are well known to those in the art, and include amplification genotyping (amplification of the desired region by suitable methods, such as PCR, followed by electrophoresis), *in situ* hybridization techniques, 5 direct DNA sequencing, etc.

The L and S alleles of the human serotonin gene which are detected in practice of the present invention are described in reference 14, the contents of which are incorporated herein by reference. The relevant portion 10 of the sequence is shown in Figure 2 herein. The L allele is shown, and the portion of that allele which is deleted in the S allele is indicated under "Deletion". The complete protein and cDNA sequences are reported (*J. Neural Transm.* 91, 67-73 (1993), incorporated herein by 15 reference) as follows:

/translation="METTPLNSQKQLSACEDGEDCQENGVLQKVVPTPGDKVESGQI  
S

20 NGYSAVPSPGAGDDTRHSIPATTTTLVAELHQGERETWGKKVDFLLSVIGYAVDLGN  
V

WRFPIICYQNGGGAFLLPYTIMAIFGGIPLFYMELALGQYHRNGCISIWKRKICPIFK  
G

25 IGYAICIIAFYIASYYNTIMAWALYYLISSEFTDQLPWTSCKNSWNTGNCTNYFSEDN  
I

TWTLHSTSPAEEFYTRHVLQIHRSKGLQDLGGISWQLALCIMLIFTVIYFSIWKGVK  
T

30 SGKVVWVTATFPYIILSVLLVRGATLPGAWRGVLFYLPKNWQKLLLETGVWIDAAQI  
F



FSLGPGFGVLLAFASYNKFNNNCYQDALVTSVVNCMTSEVSGFVIFTVLGYMAEMRNE

DVSEVAKDAGPSLLFITYAEAIAIMPASTFFAIIFFLMLITLGLDSTFAGLEGVITA

5 V

LDEFPHVWAKRRERFVLAVVITCFFGSLVTLTFGGAYVVKLLEEYATGPAVLTVALI  
E

10 AVAVSWFYGITQFCRDVKEMLGSPGWFWRICWVAISPLFLLFIICSFLMSPPQLRL  
F

QYNYPYWSIILGYCIGTSSFICIPTYIAYRLIITPGTFKERIISITPETPTEIPCG  
DIRLNAV"

15 BASE COUNT 459 a 574 c 541 g 525 t  
ORIGIN

1 GCGTGCAACC CGACGATAGA GAGCTCGGAG GTGATCCACA  
AATCCAAGCA CCCAGAGATC

20 61 CATTGGGATC CTTGGCAGAT GGACATCAGT GTCATTTACT  
AACCAGCAGG ATGGAGACGA

121 CGCCCTTGAA TTCTCAGAAG CAGCTATCAG CGTGTGAAGA  
TGGAGAAGAT TGTCAGGAAA

181 ACGGAGTTCT ACAGAAGGTT GTTCCCACCC CAGGGGACAA  
AGTGGAGTCC GGGCAAATAT

25 241 CCAATGGGTA CTCAGCAGTT CCAAGTCCTG GTGCGGGAGA  
TGACACACGG CACTCTATCC

301 CAGCGACCAC CACCACCCTA GTGGCTGAGC TTCATCAAGG  
GGAACGGGAG ACCTGGGGCA

361 AGAAGGTGGA TTTCCCTTCTC TCAGTGATTG GCTATGCTGT  
30 GGACCTGGGC AATGTCTGGC

421 GCTTCCCCTA CATATGTTAC CAGAATGGAG GGGGGGCATT  
CCTCCTCCCC TACACCATCA

481 TGGCCATTTT TGGGGGAATC CCGCTCTTTT ACATGGAGCT  
CGCACTGGGA CAGTACCACC

541 GAAATGGATG CATTTCATA TGGAGGAAA TCTGCCCGAT  
TTTCAAAGGG ATTGGTTATG  
601 CCATCTGCAT CATTGCCTTT TACATTGCTT CCTACTACAA  
CACCATCATG GCCTGGGCGC  
5 661 TATACTACCT CATCTCCTCC TTCACGGACC AGCTGCCCTG  
GACCAGCTGC AAGAACTCCT  
721 GGAACACTGG CAACTGCACC AATTACTTCT CCGAGGACAA  
CATCACCTGG ACCCTCCATT  
781 CCACGTCCCC TGCTGAAGAA TTTTACACGC GCCACGTCTT  
10 GCAGATCCAC CGGTCTAAGG  
841 GGCTCCAGGA CCTGGGGGGC ATCAGCTGGC AGCTGGCCCT  
CTGCATCATG CTGATCTTCA  
901 CTGTTATCTA CTTCAGCATC TGGAAAGGCG TCAAGACCTC  
TGGCAAGGTG GTGTGGGTGA  
15 961 CAGCCACCTT CCCTTATATC ATCCTTTCTG TCCTGCTGGT  
GAGGGGTGCC ACCCTCCCTG  
1021 GAGCCTGGAG GGGTGTCTC TTCTACTTGA AACCCAATTG  
GCAGAACTC CTGGAGACAG  
1081 GGGTGTGGAT AGATGCAGCC GCTCAGATCT TCTTCTCTCT  
20 TGGTCCGGGC TTTGGGGTCC  
1141 TGCTGGCTTT TGCTAGCTAC AACAAGTTCA ACAACAACTG  
CTACCAAGAT GCCCTGGTGA  
1201 CCAGCGTGGT GAACTGCATG ACGAGCTTCG TTTCGGGATT  
TGTCATCTTC ACAGTGCTCG  
25 1261 GTTACATGGC TGAGATGAGG AATGAAGATG TGTCTGAGGT  
GGCCAAAGAC GCAGGTCCCA  
1321 GCCTCCTCTT CATCACGTAT GCAGAAGCGA TAGCCAACAT  
GCCAGCGTCC ACTTTCTTTG  
1381 CCATCATCTT CTTTCTGATG TTAATCACGC TGGGCTTGGA  
30 CAGCACGTTT GCAGGCTTGG  
1441 AGGGGGTGAT CACGGCTGTG CTGGATGAGT TCCCACACGT  
CTGGGCCAAG CGCCGGGAGC  
1501 GGTTCGTGCT CGCCGTGGTC ATCACCTGCT TCTTTGGATC  
CCTGGTCACC CTGACTTTTG

1561 GAGGGGCCTA CGTGGTGAAG CTGCTGGAGG AGTATGCCAC  
GGGGCCCGCA GTGCTCACTG  
1621 TCGCGCTGAT CGAAGCAGTC GCTGTGTCTT GGTTCATATG  
CATCACTCAG TTCTGCAGGG  
5 1681 ACGTGAAGGA AATGCTCGGC TTCAGCCCGG GGTGGTTCTG  
GAGGATCTGC TGGGTGGCCA  
1741 TCAGCCCTCT GTTTCTCCTG TTCATCATTT GCAGTTTCT  
GATGAGCCCG CCACAACCTAC  
1801 GACTTTTCCA ATATAATTAT CCTTACTGGA GTATCATCTT  
10 GGGTTACTGC ATAGGAACCT  
1861 CATCTTTCAT TTGCATCCCC ACATATATAG CTTATCGGTT  
GATCATCACT CCAGGGACAT  
1921 TTAAAGAGCG TATTATTAAA AGTATTACCC CGGAGACACC  
AACAGAAATT CCTTGTGGGG  
15 1981 ACATCCGCTT GAATGCTGTG TAACACACTC ACCGAGAGGA  
AAAAGGCTTC TCCACAACCT  
2041 CCTCCTCCAG TTCTGAGGAG GCACGCCTGC CTTCTCCCCT  
CCGAGTGAAT GAGTTTGCC

20 A further aspect of the present invention is the  
treatment of LS heterozygote patients at increased risk  
for developing cardiovascular disease to prevent the  
development or progression of such disease. The patient  
is administered an effective amount of a material which  
25 diminishes or eliminates the adverse effects of the  
serotonin transport protein produced by the patient. The  
material may act in a number of ways which would be  
apparent to one of ordinary skill. For example, it may  
act to decrease the production of the protein, such as by  
30 affecting the DNA or RNA responsible for protein  
production, or by affecting regulatory elements. One way  
to accomplish diminished protein production is by  
introduction via gene therapy or gene repair techniques  
of a gene or gene segment which converts an L allele into

either the S allele as described herein, or an allele having the same function as the S allele. See, for example, the techniques described in U.S. Patent No. 5,776,744, the contents of which are incorporated herein  
5 by reference. The material may also act by directly or indirectly affecting the produced protein to diminish the protein's activity or effect.

It will be apparent that the information regarding a subject's genotype with respect to the HTT gene may also  
10 be used to determine whether the subject is a candidate for a therapy using a drug which prevents or treats cardiovascular disease caused by excessive production of the serotonin transport protein.

For therapeutic treatment, the materials of the present invention may be formulated into a pharmaceutical composition, which may include, in addition to an effective amount of the active ingredient,  
15 pharmaceutically acceptable carriers, diluents, buffers, preservatives, surface active agents, and the like. Compositions may also include one or more other active ingredients if necessary or desirable.  
20

The pharmaceutical compositions of the present invention may be administered in a number of ways as will be apparent to one of ordinary skill in the art.  
25 Administration may be done topically, orally, by inhalation, or parenterally, for example.

Topical formulations may include ointments, lotions, creams, gels, drops, suppositories, sprays, liquids and powders. Oral formulations include powders, granules,  
30 suspensions or solution in water or non-aqueous media, capsules or tablets, for example. Thickeners, flavorings, diluents, emulsifiers, dispersing aids or binders may be used as needed.

Parenteral formulations may include sterile aqueous solutions which may also contain buffers, diluents and other suitable additives.

5 The dose regimen of the compounds or compositions of the present invention will depend on a number of factors which may readily be determined, such as severity and responsiveness of the condition to be treated.

10 The present invention also provides a screening method for identifying materials that may be used in the treatment of a patient at increased risk for developing cardiovascular disease due to the patient being LS heterozygous for the HTTLPR insertion/deletion polymorphism at the promoter region of the serotonin transport (HTT) gene. In practice of such a method, a  
15 candidate material is screened in an assay which determines whether the material is capable of diminishing the effect of the serotonin transporter protein. Suitable assays would be readily apparent to one of ordinary skill, including animal models and *in vitro*  
20 assays. The assays may be designed to test, for example, the effect of the material on the production of the serotonin transport protein, or its effect on the activity of the protein.

The present invention also provides a kit suitable  
25 for screening a subject for any of the purposes described above (i.e., to determine whether such subject is at increased risk for developing cardiovascular disease; to determine the potential longevity of such subject; or to determine whether such subject is a candidate for the  
30 drug therapy described above). The kit comprises means for determining the subject's genotype with respect to the insertion/deletion polymorphism at the promoter region of the serotonin transport gene. Preferably, such means comprise at least two primers capable of

hybridizing to a region flanking the HTTLPR insertion/deletion polymorphism at the promoter region of the serotonin transport gene. The primers preferably are suitable for use in an amplification reaction, such as  
5 PCR. The kit additionally contains suitable packaging material, and optionally contains instructional material for use of the kit, result interpretation, etc. The kit may also contain additional reactants suitable for use with the primers, such as appropriate concentrations of  
10 deoxynucleotide triphosphates, suitable buffers, polymerization enzymes, etc.

The following non-limiting example is illustrative of the processes of the present invention.

15 EXAMPLE 1

The present study incorporated the following aspects. We had a unique opportunity to examine the potential role of genetic factors in the regulation of cholesterol levels in a healthy but elderly population of  
20 men by utilizing the participants in the Golden Games. This is a group of men over 55 years of age, who each year compete in a series of athletic competitions. Cholesterol levels and a history of the presence or absence of heart disease, angina, and heart attack, were  
25 available on these subjects (the GG group). As a replication group we also had available a group of subjects in good general health from the Loma Linda University Center for Health Promotion (the CHP group). Cholesterol and triglyceride levels were available on  
30 these subjects. As an additional replication group we examined a third group of subjects from Loma Linda University Hospital on whom a history of heart attacks was available (the LLHosp group). Since the subjects in the first two groups were in reasonably good health this

minimized the potential role of poor health as a factor in the regulation of cholesterol levels. We examined the serotonin transporter gene (HTT, SLC6A4) since the re-uptake of serotonin plays a role in the regulation of both blood serotonin (re-uptake into platelets) and brain serotonin (re-uptake into presynaptic neurons). A well-characterized insertion (L)/deletion (S) polymorphism (HTTLPR) at the promoter of the HTT gene was utilized since it is known to be associated with variations in HTT gene expression (14). Genetic variants of the HTT gene have been reported to be associated with mood disorders in some (15-19) but not all (20-22) studies. Since elevated cholesterol levels have been reported to be associated with a decreased risk for cardiovascular disease in elderly individuals (23-24), we examined the association between the HTT gene and cholesterol levels in the Golden Games subjects in two age groups 42 to 70 and >70 years of age. (There were too few subjects >70 years of to allow testing in the CHP and LLHosp group.)

**The HTT Gene.** The promoter of the human 5-hydroxytryptamine (serotonin) transporter gene (HTT) is regulated by an interplay between positive and negative regulatory elements (25). A GC-rich repetitious sequence is located in the proximal 5' regulatory region of the human HTT gene which silences transcriptional activity in nonserotonergic cells, and contains positive response elements (26). Heils, et al. (14) reported a common insertion/deletion polymorphism of this repetitive element. The deletion (short or S allele) was present in approximately one-third of the Caucasian population. Expression studies with a human choriocarcinoma cell line showed that the non-deletion or long or L allele was

associated with three times the rate of expression of the serotonin transporter compared to the S allele.

A further relevant aspect is the reported presence of molecular heterosis at the HTT gene (27, 28).

5 Molecular heterosis refers to a situation in which the heterozygotes for a polymorphic gene marker show a greater or lesser phenotypic effect than either homozygote 2S. Little, et al. (27) examined levels of [<sup>125</sup>I]β-CIT (citalopram) binding (fmol/mg) to the  
10 serotonin transporter in the dorsal and median raphe nuclei and substantia nigra of human controls and subjects with chronic cocaine use. They correlated levels of binding with the genotypes of the SS, LS, and LL alleles of the HTT LPR polymorphism of the HTT gene.  
15 This showed that [<sup>125</sup>I]β-CIT binding was lower in the LS heterozygotes than either the SS or LL homozygotes in all three regions. A two-way ANOVA was significant for genotype and region and genotype main effect ( $p < .001$ ). They also examined serotonin transporter mRNA levels in  
20 these three regions. The levels were highest for LL subjects and equally low for LS and SS subjects. Thus, the molecular heterosis effect was specific to an end function of the HTT gene in terms of [<sup>125</sup>I]β-CIT binding.

If the association between cholesterol levels and  
25 depression was due to a confounding third factor, the HTT gene would qualify as such a factor. The above three groups allowed us to determine if the HTTLPR polymorphism of the HTT gene predicted cholesterol levels, re-test this association for cholesterol and triglycerides, test  
30 if the HTT gene was associated with heart attacks, re-test this association, and to determine if the risk was different in the subjects 70 years of age or less versus those over age 70.



## Methods

**The Golden Games Group.** Each year a group of veterans, all of whom are over 55 years of age, compete in an athletic competition called the Golden Games. It is held in a different city each year and the participants are amenable to medical studies including blood drawing. The year that the Golden Games were held in Southern California we obtained blood samples for DNA and cholesterol testing. Of the 100 subjects in the present study, 74 percent were non-Hispanic Caucasian, 18 percent were African-American, and 8 percent were Hispanic or other. They ranged in age from 25 to 91 years. The mean age of the 58 subjects in the  $\leq 70$  age group was 63.9 years (S.D. 4.1 years). The mean age of the 42 subjects in the  $> 70$  age group was 74.8 (S.D. 3.1). Subjects were questioned about the presence of a history of angina, heart attacks or hypertension. In addition to coding for the presence or absence of each disorder, subjects were also coded for the number of different cardiovascular disease problems and this allowed the scoring of the "heart disease" variable.

**The Center for Health Promotion Group (CHP).** The subjects from the CHP study consisted of 102 non-Hispanic Caucasians from the Loma Linda University Center for Health Promotion. The age, sex, weight, height, and waist-hip ratio were determined on each subject. The subjects ranged in age from 42 to 70 years of age with a mean age of 55.4 years (S.D. 7.5 years). A fasting blood sample was obtained for determination of cholesterol and triglycerides. The recruitment particularly targeted staff members of the Loma Linda University, and Loma Linda University Medical Center.

**The Loma Linda Smoking Group.** The subjects from the LLHosp group consisted of a random sample of 83 non-Hispanic Caucasian male inpatients from the Jerry L. Pettis Memorial Veterans Administration Center, Loma Linda, CA, acquired from a range of hospital wards. They consisted of individuals 42 to 74 years of age with a mean age of 57.0 years (S.D. 8.87 years). There were too few subjects in the > 70 age group to analyze separately. Data on the presence or absence of heart attacks were available.

In both studies coded samples of blood were sent to the Department of Medical Genetics at the City of Hope National Medical Center where the genetic studies were performed blind to clinical data. Both studies were approved by the IRBs of both institutions.

**Laboratory tests.** Cholesterol and triglyceride levels were determined using the REP Ultra-30 HDL, VLDL/LDL Cholesterol system of Helena Laboratories (Beaumont, TX). Polymerase chain reaction genotyping of the HTTLPR polymorphism of the HTT gene was performed using conditions and similar primers to those reported by Heils, et al. (14). The forward primer had the following sequence:

GGCGTTGCCG CTCTGAATGC [SEQ ID NO:2].

The reverse primer had the following sequence:

TGGTAGGGTG CAAGGAGAAT [SEQ ID NO:3].

PCR amplification was carried out in a final volume of 25 µl containing the sample DNA, 10 mM deoxyribonucleotides, 0.1 mM of each primer, Tris-HCl, KCl, (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>, 15 mM MgCl<sub>2</sub>, 5X Q' solution, and 1.25 U of Taq DNA polymerase. PCR amplification was carried out with an initial denaturation step of 95°C for 5 minutes, 40 cycles of 95°C for 30 seconds, 64°C for 1 minute, and 72°C for 1 minute,

and final reannealing step at 72°C for 5 minutes. PCR products were run on a 7% (40% 29:1) polyacrylamide gel and visualized with ethidium bromide.

5           **Statistics.** The mean cholesterol and triglyceride levels for the different HTT genotypes were compared by ANOVA. The significance levels were determined on the basis of the F-ratio. A post hoc Tukey test indicated those means that were significantly different at  $\alpha = .05$ .  
10 Regression analysis of the correlation between cholesterol and triglyceride levels and genotype was performed scoring the HTT gene as LL or SS = 0, and LS = 1. To examine the percent of the variance for heart attack, heart disease, and angina, their presence was  
15 scored as 1, and their absence as 0. This allowed the determination of  $r^2$ , or the percent of the variance that was attributable to the HTT gene. Chi square analysis was used to compare the number of subjects with a history of heart disease, angina or heart attack in the GG group,  
20 and heart attacks in the LLHosp group, versus the LS and LL or SS HTT genotype groups. All statistical analysis was by the SPSS statistical package (SPSS, Inc. Chicago, II).

### Results

25           The results for the 100 Golden Games subjects are shown in Table 1. Since there was no significant difference in the frequencies of the LL, LS, and SS genotypes in the different racial groups, we first examined all races together. The mean cholesterol was  
30 231.41 mg/dl for the LS heterozygotes, versus 197.00 mg/dl for the LL and 206.36 mg/dl for the SS groups ( $p \leq .0056$ ). When tested for heterosis by comparing LS heterozygotes to LL+SS homozygotes, the mean cholesterol for the homozygotes was 200.65 mg/dl ( $p \leq .0017$ ). When

restricted to Caucasians the LS heterozygotes again had the higher mean cholesterol levels but the results were not significant.

When the subjects in the 55 to 70 year old group were examined for all races the mean cholesterol for the LS heterozygotes was 240.00 mg/dl, compared to 190.76 mg/dl for the LL homozygotes, and 201.00 mg/dl for the SS homozygotes ( $p \leq .0005$ ). When tested for heterosis by comparing LS heterozygotes to LL+SS homozygotes, the mean cholesterol for the homozygotes was 194.00 mg/dl ( $p \leq .0001$ ). When restricted to Caucasians the results were still significant for all three genotypes ( $p \leq .011$ ) and for heterozygotes versus homozygotes ( $p \leq .0026$ ).

By comparison, when the subjects of all races over age 70 were compared the mean cholesterol for the three groups was similar ( $p \leq .82$ ) with the level for the LS heterozygotes being only modestly greater (220.68 mg/dl) than for the homozygotes (210.38 mg/dl) ( $p \leq .53$ ). When restricted to Caucasians, the mean cholesterol for the LS heterozygotes was actually lower (210.84 mg/dl) than for the homozygotes (213.57 mg/dl) ( $p \leq .87$ ).

In an attempt to replicate these findings, we examined the CHP subjects. In addition to cholesterol levels these subjects also had triglyceride levels. Table 2 shows these results. To allow comparison to the Golden Games yet still have an adequate number of subjects, we examined individuals in the 42 to 70 year age group. There were too few subjects in the  $> 70$  year group for statistical analysis.

The mean cholesterol levels were highest for the LS heterozygotes (218.60 mg/dl), lowest for the LL homozygotes (197.44 mg/dl) and also lower for the SS homozygotes (205.46 mg/dl). While the F-values for all three genotypes were of borderline significance ( $p \leq$

.055) the Tukey test showed that the LS values were significantly higher than the LL values at  $\alpha = .05$ . The test for heterosis by comparison of heterozygotes versus homozygotes was significant ( $p \leq .019$ ).

5       The mean triglyceride levels were also highest for the LS heterozygotes (158.58 mg/dl). The levels for both the LL and SS homozygotes were similar (114.20 mg/dl and 115.20 mg/dl) and lower than for the LS heterozygotes. The F-value for all three genotypes was significant ( $p \leq .018$ ).  
10       The test for heterosis by comparison of heterozygotes versus homozygotes was significant ( $p \leq .0046$ ). When sex was used as a covariant it, sex itself was not significant for either cholesterol or triglyceride levels. When BMI was used as a covariant  
15       the association between the LS subjects and elevated cholesterol remained significant for both groups ( $p < .0001$  for the GG group,  $p < .03$  for the CHP group).

For the Golden Games subjects who were 70 years of age or less, the HTT gene accounted for 23.3 percent of  
20       the variance of cholesterol levels,  $p \leq .0001$ ; 10.2 percent of the variance for heart attack,  $p \leq .016$ ; 9.9 percent of the variance for heart disease,  $p \leq .018$ ; and 8.0 percent of the variance for angina,  $p \leq .034$ . For the CHP subjects, the HTT gene accounted for 5.3 percent  
25       of the variance of the cholesterol levels ( $p \leq .019$ ), and 9.6 percent of the variance of the triglyceride levels ( $p \leq .0066$ ).

To examine the hypothesis that the differences we observed by age group might be due to a selection  
30       process, we also examined the association between the presence of the HTT genotypes and history of heart disease, angina or heart attack for the two age ranges in the GG group. The results are shown in Table 3. For the GG group subjects less than 70 years of age, the

frequencies for those with the respective conditions in those with the LS versus the LL or SS genotype, were as follows: heart disease 68.4% versus 35.1%; angina 42.1% versus 16.2%, and heart attack 42.1% versus 13.5%. The increase in the frequency for those with the LS genotype was significant for all three diagnostic groups ( $p \leq .016$  to  $\leq .034$ ). By comparison, for those over 70 years of age there was no significant difference in the frequency for any of these heart problems in those with the LS genotypes versus the LL or SS genotypes ( $p \leq .31$  to  $1.0$ ).

In an attempt to replicate the association between the HTT alleles and heart attacks, we examined the LLHosp group (Table 3). Here 23.4% of the LS subjects had a history of a heart attack versus 5.6% of the LL or SS subjects ( $p > .030$ ).

### Discussion

Since cholesterol-lowering agents have been reported to be associated with increased violence, depression and suicide, the assumption has been that the changes in cholesterol levels are the primary effect and that changes in serotonin or other neurotransmitters, presumed to be the cause of the behavioral problems, are secondary. The present demonstration of a correlation between genetic variants of the HTT gene and serum cholesterol levels, heart disease, angina, and heart attacks, suggests that the low cholesterol and the increased depression might not be directly related but due to a third confounding factor, genetic variants of the HTT gene. While the mechanism for the association between the HTT gene and depression can be understood to be a result of the effect of the genetic variants on serotonin levels, the mechanism for the association between the HTT gene and cholesterol or triglyceride

levels is not intuitively obvious. The following are some of the possible explanations.

1. Serotonin has a direct effect on serum  
5 cholesterol levels. This would imply that blood or brain serotonin levels have a direct effect on the synthesis of degradation of cholesterol. We are unaware of such a mechanism.

10 2. Serotonin has an indirect effect on serum cholesterol levels. There are several possibilities.

a. Genetic variants of the HTT gene have been shown to be associated with mood. If LS  
15 heterozygosity was associated with depression, and depression was associated with life style changes that resulted in eating a high cholesterol diet, this could provide an indirect mechanism by which the HTT gene could be associated with high  
20 cholesterol levels. The problem with this is that the association we observed between the HTTPRL polymorphism of the HTT gene is far more robust than any reports of an association between this polymorphism and depression.

25 b. A more likely possibility is that through the well-known effect of serotonin on appetite, genetic variants of the HTT gene could be associated with obesity, which in turn is highly correlated  
30 with cholesterol levels. However, the one study of the possible association between the HTTLPR polymorphism and obesity was negative (29). To determine if the HTTLPR polymorphism was associated with weight we examined the association with an age

normalized BMI in the CHP group. There was a significantly higher BMI ( $26.0 \pm 5.0$ ) in those with the LL genotype compared to those with LS ( $23.1 \pm 4.3$ ) or SS ( $23.0 \pm 5.5$ ) genotypes ( $p \leq 0.015$ ).

5 Thus, while these results supported a role of the HTT gene in BMI, they did not support the hypothesis that the association of the LS genotype with elevated cholesterol levels was secondary to greater obesity in these individuals. Since abdominal  
10 obesity is most often associated with hypercholesterolemia and heart disease (30) we also examined the association between the HTTLPR polymorphism and the age normalized waist-hip ratios in the CHP group. This ratio was highest for those  
15 with the LS genotype ( $.89 \pm .10$ ) compared to those with the LL ( $.85 \pm .09$ ) or the SS ( $.86 \pm .09$ ). However, this was not significant ( $p \leq .25$ ).

3. The indirect effect is through a third  
20 confounding covariant. The identity of this possible confounding covariant is unknown.

When all factors are considered, we believe the most likely explanation for the association between genetic  
25 variants of the HR gene and serum cholesterol levels is through the effect of serotonin on appetite and abdominal obesity. However, while a larger series of cases might show a significant correlation between the HR gene and abdominal obesity, as measured by waist:hip ratio, our  
30 results suggest it will not be as robust as the association with cholesterol and triglyceride levels. This suggests other factors associated with a more direct effect of the HTT gene on cholesterol levels and heart disease are involved. These potential interactions



between genotypes of the HTT gene, cholesterol levels, depression, and cardiovascular disease are summarized in Figure 1. The LS genotype may exert part of its effect on cholesterol levels and cardiovascular disease through an effect on appetite. There may also be an unknown direct effect on cholesterol levels and on abdominal obesity. Much of the association between the LS genotype and cardiovascular disease may be through the well known role of serotonin on vascular constriction, essential and pulmonary hypertension, platelet aggregation, thrombosis and atheromata formation (31-35). By contrast, the S allele and the SS genotype, may independently exert an effect on serum cholesterol levels and, through its regulation of synaptic serotonin levels, depression.

In addition to the association of the HTTLPR polymorphism with cholesterol and triglyceride levels, the other aspect of interest was the difference in the effect of the HR gene variants on subjects less than 70 years of age versus subjects greater than 70 years of age. This difference was only observed in the Golden Games subjects because they were the only group with a sufficient number of subjects over 70 to have statistical validity. The pattern for cholesterol levels, heart disease, angina, and heart attack were all similar. Thus, the effect was greater for LS heterozygotes for all of these variables only in the less than 70 age group. It disappeared or was negative (less effect in the LS heterozygotes) in the over 70 age group. While the number of subjects are still too small for definitive conclusions, we believe the most parsimonious explanation is that the LS heterozygotes who are at greatest risk tend to die at an earlier age. Thus, the LS heterozygotes with elevated cholesterol levels and

elevated risk for cardiovascular disease, are missing from the older age group.

A final aspect of this study is the question of whether it is relevant to the apparent association between low cholesterol levels and depression, or to the observation that an elevated cholesterol level becomes less of a risk factor for cardiovascular disease or premature death in older subjects. It would seem that since HTT gene variants are modestly associated with both affective disorders and serum cholesterol, the association between low cholesterol and depression could be due to the HTT gene as a confounding third factor. Based on the present results, the specific hypothesis would be that since LS heterozygosity is associated with elevated cholesterol levels, then LL or SS homozygosity, associated with lower cholesterol levels would be the genotypes associated with depression. The literature suggests this is the case. Those studies that have reported a positive association between the HTTLPR polymorphism and affective disorder have reported the association to be with the SS genotype, or S allele (36). Thus, in population based studies, individuals with the SS genotype would have lower cholesterol levels and greater levels of depression. However, since the S allele is associated with lower rates of synthesis of the 5-HT transporter, this should be associated with elevated levels of synaptic serotonin and less depression. This paradox has been commented on by Collier, et al. (18) and Routledge and Middlemiss (37). The latter authors suggested that the decreased expression of the H17 gene by the S allele results in a modest elevation of raphe serotonin levels, but this produces an enhanced negative feedback via somatodendritic 5-HT<sub>1A</sub> receptors resulting in an overall decrease in terminal serotonin output.

The second issue is whether the present findings can explain the fact that an elevated cholesterol level is less of a risk factor for cardiovascular disease in older individuals. This decreased risk in older subjects seems to parallel our observation that the association of the LS genotype with elevated cholesterol levels, heart disease, angina, and heart attack also disappeared in the over 70 age group. Our hypothesis that the latter is due to the premature death of LS subjects, and could also explain why elevated cholesterol levels are no longer a risk factor in this age group, *i.e.* those LS subjects at greatest risk because of elevated levels of cholesterol and an elevated risk for heart disease associated with the HTT gene - die prematurely. Those who are left have elevated cholesterol levels due to non-genetic reasons or different genetic reasons, and in these subjects, perhaps because serotonin is not involved, an elevated cholesterol level *per se* does not have the same dire consequences. Further studies of the role of other serotonin genes in cardiovascular disease are in progress.

**Table 1. Association between the Genotypes of the HTT Gene and Serum Cholesterol Levels in Golden Games Males in Two Age Groups**

5

	Genotype	N	Mean (mg/dl)	S.D.	F	p
	Age All races (HTTLPR) (n = 100)					
10	LL	39	197.00	41.45		
	LS	36	231.41*	48.30		
	SS	25	206.36	49.10	5.48	≤.0056
15	LL+SS	64	200.65	48.30		
	LS	36	231.41	48.30	10.36	≤.0017
	Age Caucasians only (HTTLPR) (n = 72)					
20	LL	25	205.20	41.52		
	LS	27	227.63*	40.82		
	SS	20	208.05	53.55	1.89	≤.158
	LL+SS	45	206.46	46.69		
25	LS	27	227.62	47.12	3.79	≤0.55
	Age 55 to 70 All races (HTTLPR) (n = 58)					
	LL	26	190.76	42.11		
30	LS	20	240.00#	44.05		
	SS	12	201.00	28.41	8.72	≤.0005
	LL+SS	38	194.00	38.22		
	LS	20	240.00	44.05	17.07	≤.0001

Table 1 (continued)

	Genotype	N	Mean	S.D.	F	p
	<b>Age 55 to 70 Caucasians only (HTTLPR) (n = 38)</b>					
5	LL	16	199.37	39.95		
	LS	14	243.21	44.93		
	SS	8	202.00	28.71	5.11	≤.011
	LL+SS	24	200.25	35.96		
10	LS	14	243.21	44.93	10.49	≤.0026
	<b>Age &gt; 70 All races (HTTLPR) (n = 42)</b>					
	LL	13	209.46	38.67		
	LS	16	220.68	52.58		
15	SS	13	211.31	63.45	.194	≤.82
	LL+SS	26	210.38	51.51		
	LS	16	220.68	52.58	.390	≤.53
20	<b>Age &gt; 70 Caucasians only (HTTLPR) (n = 34)</b>					
	LL	9	215.55	44.60		
	LS	13	210.84	28.91		
	SS	12	212.08	66.21	.025	≤.97
25	LL+SS	21	213.57	28.91		
	LS	13	210.84	28.91	.025	≤.87

\*Significantly different from LL by Tukey test at  $\alpha = .05$ .

30 #Significantly different from LL and SS by Tukey test at  $\alpha = .05$ .

**Table 2. Association between the Genotypes of the HTT Gene and Serum Cholesterol and Triglyceride Levels in CHP Males and Females 42 to 70 years of age (n = 102)**

5	Genotype	N	Mean (mg/dl)	S.D.	F	p
	<b>Cholesterol</b>					
	LL	34	197.44	32.98		
	LS	55	218.60*	43.11		
	SS	13	205.46	44.62	2.99	≤.055
10	LL+SS	47	199.65	36.23		
	LS	55	218.60	42.78	5.65	≤.019
	<b>Triglycerides</b>					
15	LL	34	114.20	71.76		
	LS	55	158.58*	84.03		
	SS	13	115.20	53.11	4.15	≤.018
	LL+SS	47	114.55	66.56		
20	LS	55	158.58	84.03	8.39	≤.0046

\*Significantly different from LL by Tukey test at  $\alpha = .05$ .

**Table 3. *HTT* Genotype and History of Angina, Heart Disease or Heart Attack (% yes or no, all 1 d.f.)**

Condition  --- <i>HTT</i> Genotype----		Chi Square		p
5	<b>GOLDEN GAMES</b>			
	<b><u>A. Heart disease</u></b>			
	<b>Age 55 to 70 All races (HTTLPR) (n = 56)</b>			
		<b>LS</b>	<b>LL+SS</b>	
10	<b>Yes</b>	13 (68.4)	13 (35.1)	
	<b>No</b>	6 (31.6)	24 (64.9)	5.59 ≤.018
	<b>Age &gt; 70 All races (HTTLPR) (n = 42)</b>			
		<b>LS</b>	<b>LL+SS</b>	
15	<b>Yes</b>	8 (50.0)	13 (50.0)	
	<b>No</b>	8 (50.0)	13 (50.0)	.000 ≤1.00
	<b><u>B. Angina</u></b>			
	<b>Age 55 to 70 All races (HTTLPR) (n = 56)</b>			
20		<b>LS</b>	<b>LL+SS</b>	
	<b>Yes</b>	8 (42.1)	6 (16.2)	
	<b>No</b>	11 (57.9)	31 (83.8)	4.48 ≤.034
	<b>Age &gt; 70 All races (HTTLPR) (n = 42)</b>			
		<b>LS</b>	<b>LL+SS</b>	
25	<b>Yes</b>	5 (31.3)	8 (30.8)	
	<b>No</b>	11 (68.8)	18 (69.2)	.001 ≤.97

Table 3 (continued)

Condition	---HTT Genotype---	Chi Square	p
<u>C. Heart attack</u>			
5	Age 55 to 70 All races (HTTLPR) (n - 56)		
	LS	LL+SS	
	Yes	8 (42.1)	5 (13.5)
	No	11 (57.9)	32 (86.5)
			5.75
			≤.016
10	Age > 70 All races (HTTLPR) (n - 42)		
	LS	LL+SS	
	Yes	6 (37.5)	6 (23.1)
	No	10 (62.5)	20 (76.9)
			1.00
			≤.31
15	LLHosp GROUP		
	<u>Heart attack (n = 83)</u>		
	LS	LL+SS	
	Yes	11 (23.4)	2 (5.6)
	No	36 (76.6)	34 (94.4)
			4.91
			≤.03
20			



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## CLAIMS

1. A method for screening a subject to determine whether such subject is at increased risk for developing cardiovascular disease, said method comprising  
5 determining the subject's genotype with respect to the serotonin transport (HTT) gene, wherein an LS heterozygote for the HTTLPR insertion/deletion polymorphism at the promoter region of the HTT gene has  
10 an increased risk for developing said disease.
2. The method of claim 1, wherein the disease is selected from the group consisting of elevated cholesterol, angina and heart attack.  
15
3. The method of claim 1, wherein said analysis is performed by sequencing.
4. The method of claim 1, wherein said analysis is performed by amplification of at least a portion of the  
20 promotor region.
5. The method of claim 1, wherein said analysis is performed by a hybridization reaction.  
25
6. The method of claim 5, wherein the hybridization reaction is an *in situ* hybridization.
7. A method for screening a subject to determine  
30 the potential longevity of such subject, said method comprising determining the subject's genotype with respect to the serotonin transport (HTT) gene, wherein an SS homozygote for the HTTLPR insertion/deletion

polymorphism at the promoter region of the HTT gene has a greater probability of survival past eighty years of age.

5 8. The method of claim 7, wherein said analysis is performed by sequencing.

9. The method of claim 7, wherein said analysis is performed by amplification of at least a portion of the promoter region.

10

10. The method of claim 7, wherein said analysis is performed by a hybridization reaction.

11. The method of claim 10, wherein the  
15 hybridization reaction is an *in situ* hybridization.

12. A method for treating a patient at increased risk for developing cardiovascular disease due to the patient being LS heterozygous for the HTTLPR  
20 insertion/deletion polymorphism at the promoter region of the serotonin transport (HTT) gene, said method comprising administering to said patient an effective amount of a material which diminishes the effect of the serotonin transporter protein.

25

13. The method of claim 12, wherein the material causes a decrease in production of said protein.

14. The method of claim 12, wherein the material  
30 causes a decrease in the activity of said protein.

15. A method for identifying materials that can be used in the treatment of a patient at increased risk for developing cardiovascular disease due to the patient



being LS heterozygous for the HTTLPR insertion/deletion polymorphism at the promoter region of the serotonin transport (HTT) gene, said method comprising determining whether the material is capable of diminishing the effect of the serotonin transporter protein.

16. The method of claim 15, which comprises determining whether the material is capable of causing a decrease in production of said protein.

17. The method of claim 15, which comprises determining whether the material is capable of causing a decrease in the activity of said protein.

18. A pharmaceutical composition which comprises  
a) an effective amount of a material which is capable of diminishing the effect of the serotonin transporter protein in a patient being LS heterozygous for the HTTLPR insertion/deletion polymorphism at the promoter region of the serotonin transport (HTT) gene; and

b) a pharmaceutically acceptable carrier.

19. The composition of claim 18, wherein the composition is capable of causing a decrease in production of said protein.

20. The composition of claim 18, wherein the composition is capable of causing a decrease in the activity of said protein.

21. A method for screening a subject to determine whether such subject is a candidate for a therapy using a drug which prevents or treats a cardiovascular disease

associated with excessive production of the serotonin transport protein, said method comprising determining the subject's genotype with respect to the serotonin transport (HTT) gene, wherein an LS heterozygote for the HTTLPR insertion/deletion polymorphism at the promoter region of the HTT gene is a candidate for such therapy.

22. A kit suitable for screening a subject to determine whether such subject is at increased risk for developing cardiovascular disease, said kit comprising

- a) means for determining the subject's genotype with respect to the insertion/deletion polymorphism at the promoter region of the serotonin transport gene;
- b) suitable packaging material; and optionally
- c) instructional material for use of said kit.

23. The kit of claim 22, wherein component a) comprises at least two primers capable of hybridizing to a region flanking the HTTLPR insertion/deletion polymorphism at the promoter region of the serotonin transport gene.

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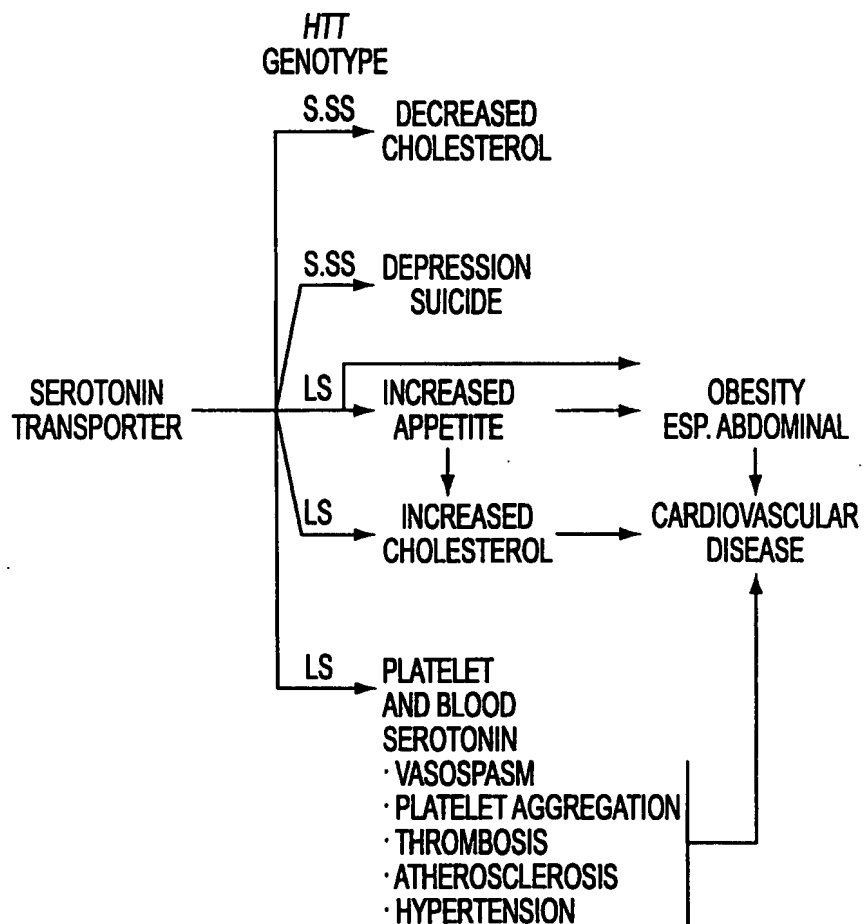


FIG. 1

2/2

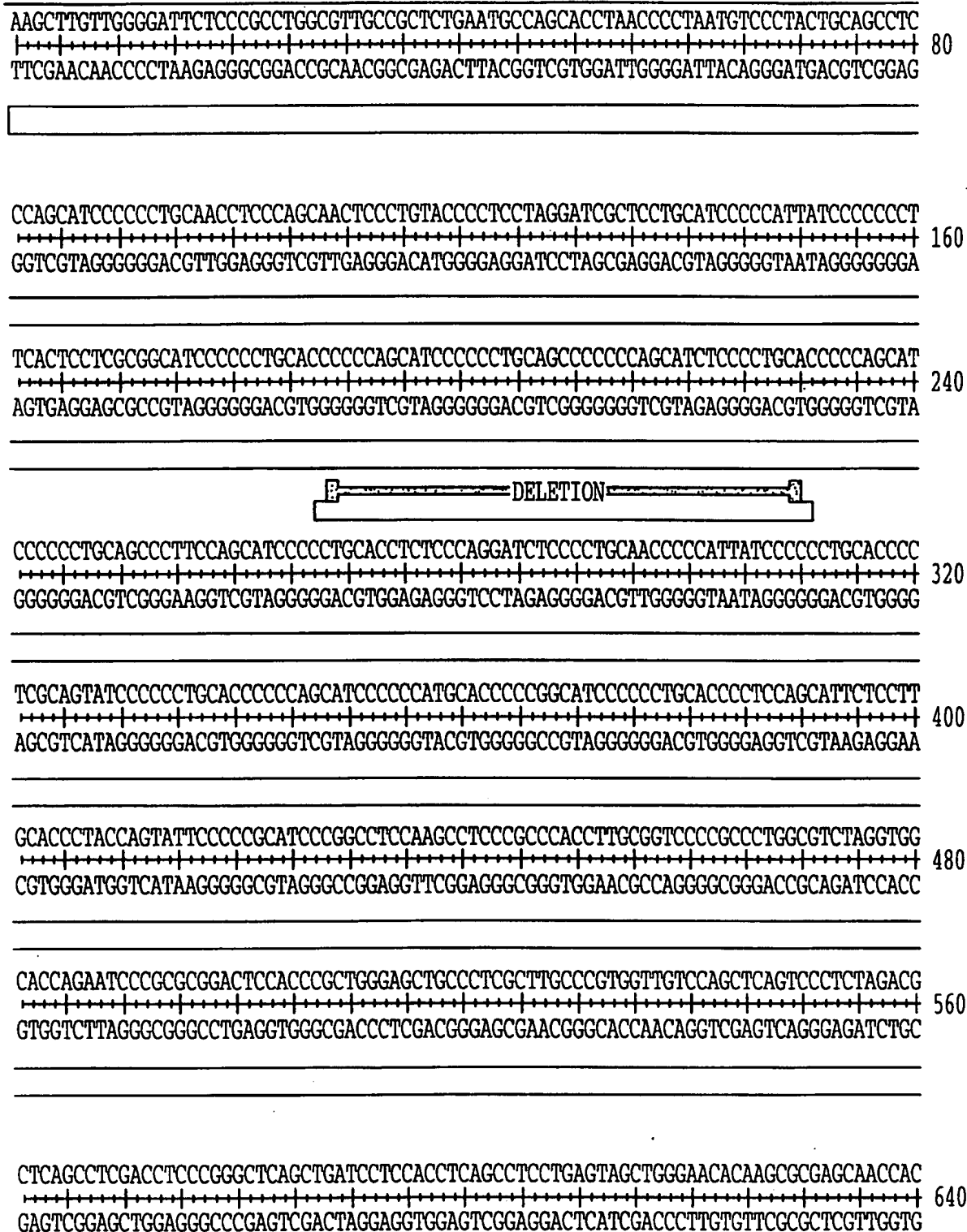


FIG. 2

SUBSTITUTE SHEET (RULE 26)